LOW-TEMPERATURE REFLECTIVITY SPECTRA OF FERRIC MINERALOGIES: IMPLICATIONS FOR IDENTIFICATION OF MINERAL PHASES ON MARS.

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INTRODUCTION

Comparison of remote sensing data for Mars at visible and near-IR wavelengths to corresponding data for hematite and hematite-bearing materials has led to the inference that red (i.e., well-crystalline and pigmentary) hematite is a subordinate pigmenting phase on the optical surface of Mars where the hematite band minimum near 850-870 nm is present [e.g., 1-6]. The dominant pigmenting phase is likely a nanophase ferric oxide (perhaps nanophase hematite [1,4]) that is responsible for the ferric absorption edge but does not contribute a definable ferric band minimum. Because the laboratory spectra were obtained at room temperatures and the Martian surface temperature varies between ~140 and 300 K (average ~210 K) [7], the inference presumes that the position, number, and intensity of the spectral features of red hematite are not significant functions of temperature. We have recently shown [3] that low-temperature spectra of synthetic hematite powders and hematite-bearing natural samples are consistent with the identification of hematite on Mars. In fact, the significant increase in reflectivity near 600 nm observed for red hematite with decreasing temperature is additional evidence for its presence on the planet. To rigorously demonstrate that the Martian band near 850-870 nm does not result from other ferric mineralogies, it is necessary to know their spectral properties at low-temperatures. Reported here are low-temperature reflectivity data for eight additional ferric mineralogies (Table 1: maghemite, goethite, lepidocrocite, akaganeite, ferrihydrite, jarosite, schwertmannite, and nontronite). Methods are described by [3].

RESULTS AND DISCUSSION

The temperature dependence of two ferric spectral features are shown in Figures 1 and 2. 4T1G refers to minimum in reflectivity arising from the $^6A_1 \rightarrow {}^4T_{1g}$ single electron transition of ferric iron. RMX1 refers to the relative reflectivity maximum between the $^6A_1 \rightarrow {}^4T_{1g}$ and $^6A_1 \rightarrow {}^4T_{2g}$ transitions. As shown in Figure 1, the magnitude of change in the position of the 4T1G band minimum with temperature is highly variable from mineral to mineral (range +15 to -55 nm) between 303 and 130 K. Changes in the 4T1G minimum for hematite (HMS3, HMS12, and HMS14) and 2-line ferrihydrite (FEH2LS1) are comparable to experimental error (±12 nm for ferrihydrites; ±6 nm for all others) and may not be real. Jarosite (LNVJAR1) is the only mineralogy whose 4T1G minimum shifts to higher wavelengths (lower energies) with decreasing temperature. For maghemite (MHS4), the goethites (GTS2 and GTS3), lepidocrocite (LPS2), akaganeite (AKS1), and 6-line ferrihydrite (FEH6LS1), the 4T1G minimum shifts to lower wavelengths (higher energies) with decreasing temperature. Some of these negative shifts are quite large (-40, -45, and -55 nm for AKS1, BT-4, and GTS2, respectively).

For Mars, the position of the 4T1G minimum is variable, but ranges between 850 and 870 nm for a number of bright regions [6,8]. According to Figure 1 and in agreement with previous results [e.g., 3], the Martian spectra are consistent with the presence of red hematite. A new result is that the 4T1G minimum for akaganeite at low temperatures is also consistent with Martian data. Figure 2 is a plot of RMX1 versus 4T1G and shows, in general, that RMX1 is less dependent on temperature than 4T1G. The only exception appears to be 2-line ferrihydrite. The data for all hematites (at all temperatures) plot within the field for Martian bright regions. The datum for akaganeite, however, does not plot in the Martian region, suggesting that the phase is actually not optically important on Mars.

Spectra of other Martian bright regions have a band minimum near 900 nm. This wavelength implies the presence of maghemite, goethite, ferrihydrite, jarosite, and/or schwertmannite (Figure 1 and [e.g., 6,9,10]; it does not imply hematite. Unfortunately, these spectra do not extend to wavelengths shorter than ~750 nm (Phobos-2 mission [6]) so it is not possible to use Figure 2 to discriminate among phases.

In summary, low-temperature reflectivity spectra for hematite and eight other ferric oxide, oxyhydroxide, sulfate, and silicate phases are consistent with the presence of red (pigmentary and well crystalline) hematite and the absence of the other phases on the optical surface of Mars characterized by a band minimum near 860 nm.

Table 1. Name, mineralogy, chemical formula, and references to other data for samples used in this study.

Name	Mineralogy	Formula	Ref.
HMS3	Hematite	α-Fe_2O_3	3,8
HMS12	Hematite	α-Fe_2O_3	3,8
HMS14	Hematite	α-Fe_2O_3	3,8
MHS4	Maghemite	γ-Fe_2O_3	8
GTS2	Goethite	α-FeOOH	8
GTS3	Goethite	α-FeOOH	8
LPS2	Lepidocrocite	γ-FeOOH	8
AKS1	Akaganeite	β-FeOOH	
FEH2LS1	2-line Ferrihydrite	$5Fe_2O_3.9H_2O$	
FEH6LS1	6-line Ferrihydrite	$5Fe_2O_3.9H_2O$	
LNVJAR1	Jarosite	$(Na,K)Fe_3(SO_4)_2(OH)$	9
BT-4	Schwertmannite	$Fe_{16}O_{16}(OH)_y(SO_4)_z$	10
PAN1	Nontronite	$Na_{0.33}Fe_2(Si,Al)_4O_{10}$	

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